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Standard Weight for Height Curves in Achondroplasia

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Standard curves developed for the general population cannot be used to assess the growth of an individual who has a condition that results in disproportionate short stature. For this reason, efforts have been made to develop growth curves specific for several of the chondrodysplasias. However, data concerning weight for height have been largely lacking, although they may be of particular importance for conditions such as achondroplasia, where there is some consensus that an increased prevalence of obesity is a particular problem. In this paper we provide standard weight for height curves for males and females with achondroplasia, and discuss the use of several indices which have been applied to the assessment of body fat in the general population.

KEY WORDS: achondroplasia, weight, height, obesity

INTRODUCTION

Those who care for individuals who are short because of a chondrodysplasia place considerable emphasis on the avoidance of obesity. There is some consensus that, in addition to the risks posed by obesity in the general population, extra weight in those with chondrodysplasias may cause stress on susceptible bones and joints, resulting in premature neurologic and orthopedic complications. While in most of these conditions obesity may simply reflect excess weight being more visible on a small frame [Scott, 1977], there is some concern that individuals with achondroplasia may be particularly susceptible to excessive weight gain [Hecht et al., 1988; Owen et al., 1990]. Counterintuitive to these convictions was the finding of Owen et al. [1990] that the mean resting metabolic rate in a group of adult achondroplastic dwarfs was greater than that of average-size adults.

Standardized curves of weight for height are available for the general population where, in addition, a number of indices have been developed and validated to enable an estimation of body fat. These include the use of skin-fold thickness [Jackson and Pollock, 1985; Revicki and Israel, 1986], and of weight-to-height (W/H) relationships (e.g., W/H^2, W/H^3) [Rolland-Cachera et al., 1982]. In order to be considered valid, such indices should have a low correlation with height and a high correlation with weight. In the general population it is clear that no one method works best across differences in sex and age, and that they can all significantly err in the estimation of body fat in an individual [Cronk and Roche, 1982; Rolland-Cachera et al., 1982; Revicki and Israel, 1986].

However, there has been relatively limited application or critical assessment of the use of these indices in individuals with achondroplasia. Hecht et al. [1988] found a moderate correlation of the Quetelet index (W/H^2) with skin-fold thickness, but they did not assess the validity of either as an estimate of body fat. Owen et al. [1990], using a relatively small sample of adults with achondroplasia, concluded that skin-fold thickness provided the best correlations but still led to wide errors if used to predict body fat in individual patients. They stated, "until more accurate methods are developed, that underwater weighing, if possible, should be used to estimate the body fat mass of dwarfs."

Underwater weighing is clearly not possible or even desirable under normal circumstances. What is required in general clinical practice is a simple assessment as to whether weight is appropriate for height in an individual. While the W/H ratio in itself is a poor measure of body fat because it is highly correlated with height, standard weight-for-height curves do provide an immediate grasp of where an individual lies relative to the mean weight for that height of achondroplastic dwarf. Together with some clinical judgment as to whether an individual is truly obese, or heavy because of a muscular build, these curves can also be used to set a target weight for height. Curves that are specific for diagnosis avoid the concern about the impact of differing body proportions. This paper reports W/H curves

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for achondroplasia from birth to adulthood, and briefly examines the correlations of height and weight with some commonly used indices.

MATERIALS AND METHODS

The individuals in this study were all of mixed European, Caucasian ancestry. Their source and number, and the total number of paired heights and weights recorded, are shown in Table I. Those recorded as "previously reported" are from the data set of Hecht et al. [1988]. Patients from that study under age 1 year were excluded because of an apparent rounding of weights to the nearest kilogram. The remaining data were extracted from hospital and clinic files, or recorded at the time of a personal interview (total 88) concurrent with other aspects of a study involving a variety of chondrodysplasias.

The largest single data source (Wilmington, DE) had been recorded by the same individual (C.I.S.), with a constant technique of bare feet on a firm surface, with a nonstretching tape, and a block squared to the wall. The major proportion of the remaining heights was measured in this way. Weights were mostly recorded from a standard balance scale, or in more recent cases, from electronic digital scales. Sitting heights (SH) were recorded with the subject sitting on a firm surface, and otherwise as described above for standing heights.

Skin-fold thicknesses were performed as previously described [Hecht et al., 1988], or with Lange (Cambridge Scientific, Cambridge, MD) callipers and standard technique for abdominal, scapular, and triceps sites [Jackson and Pollock, 1985]. Any imperial data were converted to metric, accurate to two decimal places, and all data were entered into Statistical Package for Social Scientists (SPSS/PC+) for analysis. Recording and data entry errors were first sought by scanning the SPSS spreadsheets and histograms of weight for age and height. Height was then recoded into 2-cm intervals for analysis (e.g., 109.1–111.0 cm = 110 cm), and the means and standard deviations (SD) of weight for each height interval were calculated. These results were then scrutinized for any break in trends or sudden spread in SD. In this way, a few data entry errors were found, and 3 extremely obese individuals were excluded from the analysis. Following reanalysis, the data were plotted using Harvard Graphics (Mountain View, CA). The mean and range of the number of measurements taken at different height intervals are summarized in Table I.

Actual (nonrecoded) heights were used to calculate W/H, W/H^2 (Quetelet index), and W/H^3 (Rohrer index), and to calculate the correlation coefficients with both raw and log-transformed data.

RESULTS

The mean weight for height for males is shown in Figure 1, and for females in Figure 2. The 97th centile for the general population is included for comparison [Hamill et al., 1979]. The curves for both sexes remain quite smooth, with relatively small standard deviations up to about 104–106 cm in height, representing an age of 10–11 years. As would be expected beyond late childhood, the lower number of observations, and the inherent greater variability in weight with increasing height and age, combine to produce a more irregular curve with wider ranges of standard deviation.

The mean W/H is virtually identical to the 97th centile for the average population for both achondroplastic males and females to a height of about 75 cm, at which point the curves gradually, and then more rapidly, rise above those of the general population. It should be noted that children with achondroplasia are about 3

TABLE IA. Source of Cases and Total Number of Paired Height/Weight Recordings

Source	Number of subjects	Number of observations
Cardiff, UK	1	1
Wilmington, DE	109	615
Manchester, UK	12	13
Melbourne, Australia	22	173
Sydney, Australia	49	113
Ottawa, Canada	2	9
Previously reported	214	223
Total	409	1,147 (female, 516; male, 631)

TABLE IB. Mean and Range of Number of Measurements Per Height Interval

Sex	Range of height	Measurement per 2-cm interval	
		Mean	Range
Male	44–92 cm	16.8	6–30
Female	44–92 cm	12.8	4–22
Male	94–132 cm	8.7	5–14
Female	94–132 cm	7.3	4–24
Male	>132 cm	5.1	1–12
Female	>132 cm	1.5	1–2

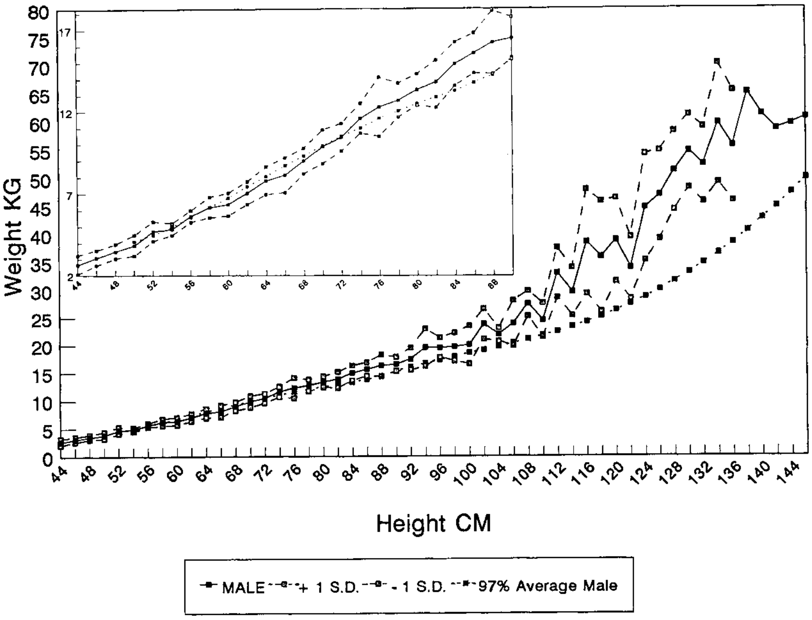


Fig. 1. Mean ±1 SD weight/height curve for male achondroplasia, with 97th centile for general population shown for comparison. Values to 90 cm are enlarged as an insert.

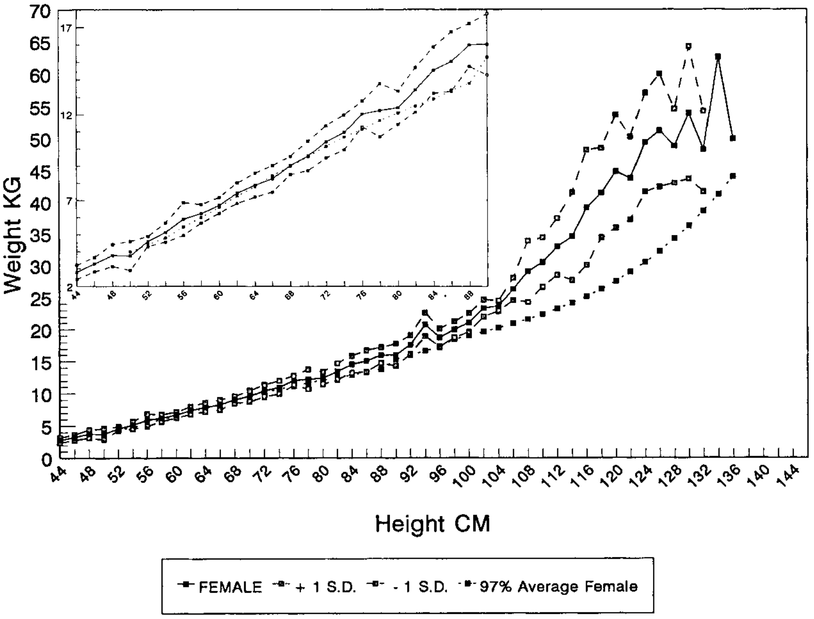
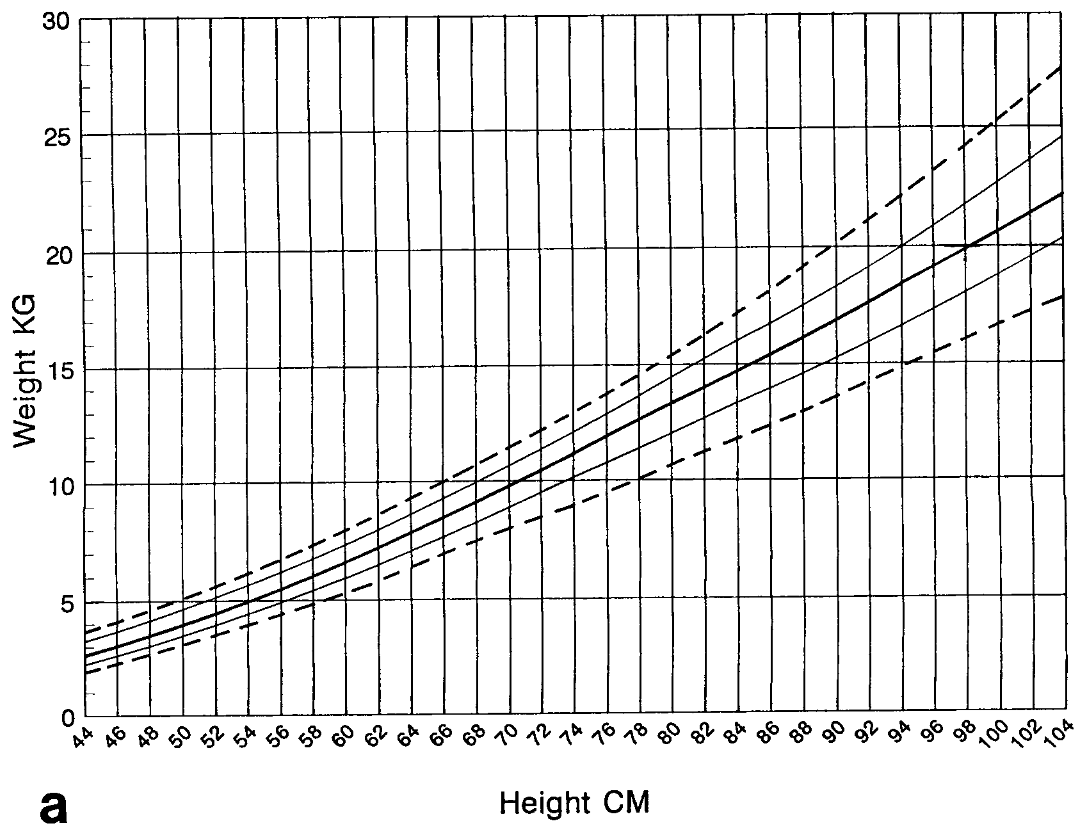


Fig. 2. Mean ±1 SD weight/height curve for female achondroplasia, with 97th centile for general population shown for comparison. Values to 90 cm are enlarged as an insert.

years old at the height of 75 cm, and are likely to be measured standing, while the curve shown for the general population is supine to 90 cm [Hamill et al., 1979]. The apparent "loss" of height with standing will increase the W/H ratio slightly.

Separate smoothed curves for mean W/H, ±1 and 2 SD for heights up to 104 cm, are shown in Figure 3a,b for males and females, respectively. Similar curves for 104 cm and above are provided in Figure 4a,b.

Table II summarizes the correlation coefficients for height and weight with sitting height (SH), weight divided by height (W/H), W/H^2, W/H^3, and scapular (SSF), abdominal (ASF), and triceps (TSF) skin-fold thicknesses, across all ages and for specific age groups. Log-transformed data were also examined, but as they tended to increase the correlation with height, which is contrary to the requirements for an index of body fat, they are not presented here.



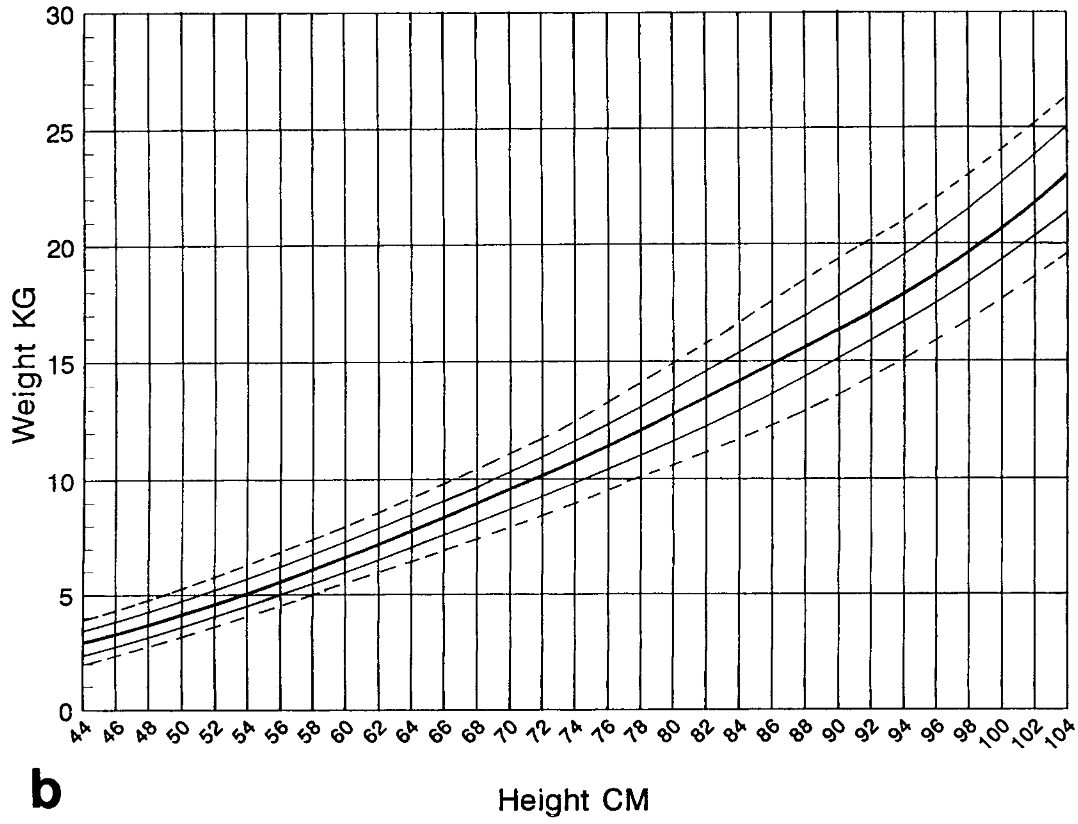
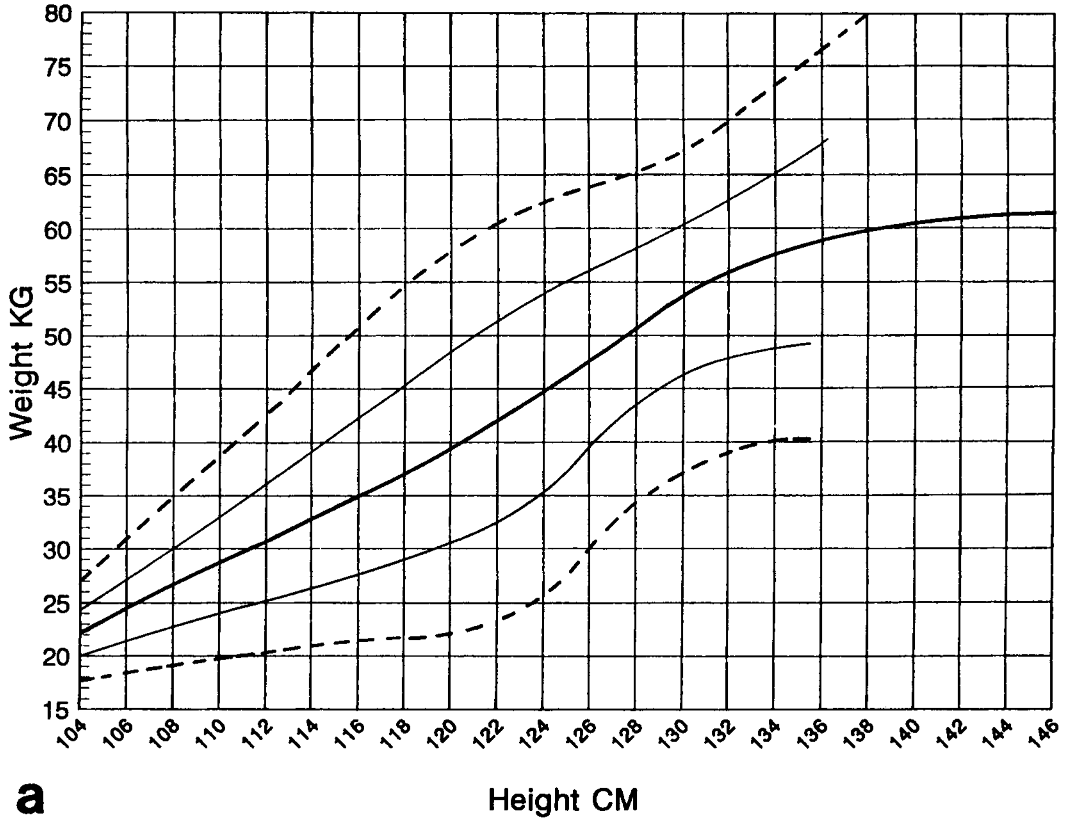


Fig. 3. **a:** Smoothed mean, ±1 and 2 SD, weight/height curves to 104 cm for males with achondroplasia. **b:** Smoothed mean, ±1 and 2 SD, weight/height curves to 104 cm for females with achondroplasia.



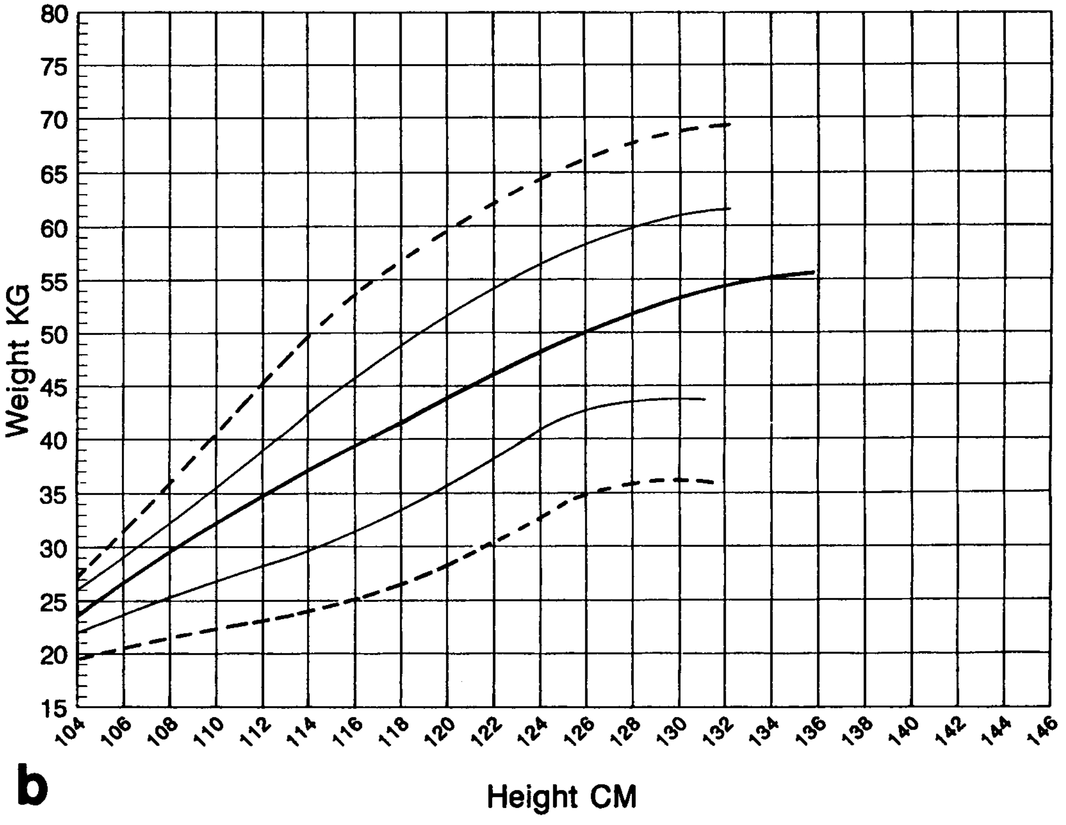


Fig. 4. **a:** Smoothed mean, ±1 and 2 SD, weight/height curves >104 cm for males with achondroplasia. **b:** Smoothed mean, ±1 and 2 SD, weight/height curves >104 cm for females with achondroplasia.

TABLE II. Correlation Coefficients of Weight and Height With Several Indices of Body Fat at Different Ages*

		Ht	SH	W/H	W/H^2	W/H^3	SSF	ASF	TSF
All ages	Ht		0.98	0.92	0.80	−0.591	0.62	0.48	0.37
	Wt	0.93	0.94	0.99	0.92	−0.27	0.74	0.57	0.57
Over 18 years	Ht		0.76	0.79	0.61	−0.34	−0.05	−0.10	−0.08
	Wt	0.83	0.53	0.98	0.90	0.18	0.50	0.41	0.46
6–18 years	Ht		0.96	0.81	0.58	−0.03	0.43	0.36	0.38
	Wt	0.89	0.93	0.99	0.88	0.42	0.57	0.53	0.59
3–<6 years	Ht		0.83	0.59	0.03	−0.57	0.36	−0.06	0.42
	Wt	0.82	0.80	0.94	0.59	−0.01	0.53	0.15	0.66
<2 years	Ht		0.85	0.91	0.63	−0.42			−0.09
	Wt	0.96	0.83	0.98	0.80	−0.11			0.24

*SSF, scapular skin-fold; ASF, abdominal skin-fold; TSF, triceps skin-fold, W/H, weight divided by height; Ht, height; Wt, weight; SH, sitting height. Coefficients in boxes are discussed in text.

None of the indices meet the criteria of low correlation with height and high correlation with weight across all ages or below age 2 years. Skin-fold thickness appears to have some validity over age 18 years, once linear growth has ceased (*P* values are not significant for height, but are highly significant for weight). The mean skin-fold thickness for age at each measured site is shown in Figure 5, as well as the average of scapular and triceps. Also plotted are the mean skin-fold thicknesses for individuals on whom a notation of "obese" had been made at the time of interview.

From age 6–18 years, the Rohrer index (W/H^3) appears to be the best, although correlation with weight is only moderate ($r = 0.42$, $P < 0.001$). The mean W/H^3 by age is plotted in Figure 6, together with individual values of W/H^3 for those children whose weight was ≥1 SD above mean weight for age of subjects in this study (data not shown). Finally, the Quetelet index (W/H^2) appears best-suited for children between age 36–72 months, during which time the mean value (Fig. 7) of the index remains virtually constant, between 20–21. Also plotted in Figure 7 is the 97th centile of the average population [Rolland-Cachera et al., 1982], and individual W/H^2 values for children whose weight was ≥1 SD above the mean weight for age of subjects in this study (data not shown).

DISCUSSION

There is a consensus that individuals with achondroplasia are particularly likely to become obese, and that this may have a deleterious effect upon their long-term health. However, efforts to determine the magnitude of this problem are thwarted by the inability to apply general population data and indices to individuals with disproportionately short stature, and by the lack of adequate normative weight data specific to achondroplasia. Hecht et al. [1988] found that, of 195 individuals with achondroplasia, 19% of males and 9% of females had triceps skin-fold thicknesses >95th centile, and that the comparable figures for the W/H^2 index were 46% and 42%, respectively. They concluded that between 13–43% of their patients were obese. However, Owen et al. [1990] showed that these, as well as more complex indices, were poor indicators of body fat, although skin-fold thickness gave the best approximation. We have confirmed that, over age 18 years, skin-fold thickness shows no correlation with height, and a moderate, but highly significant, correlation with weight. Indeed, all individuals who had been recorded

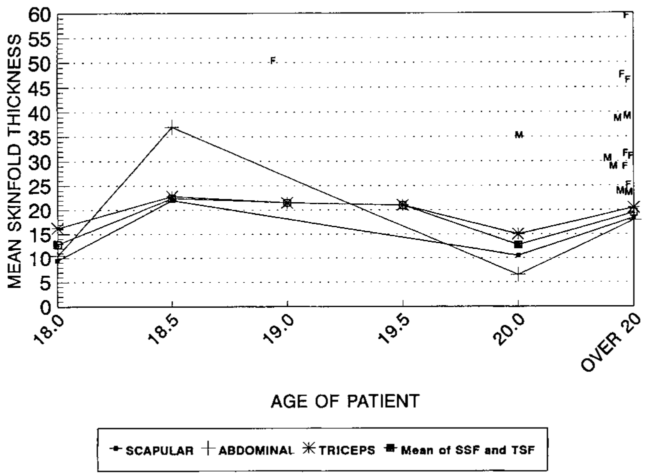


Fig. 5. Mean scapular, triceps, and abdominal skin-fold thicknesses for individuals over age 18 years. Included are individual values for men (M) and women (F) noted as obese at time of interview.

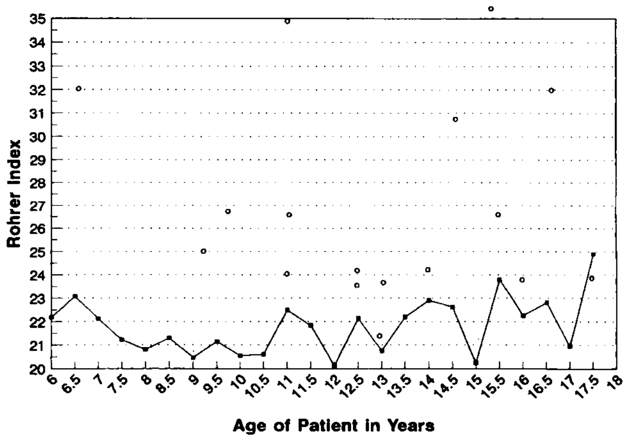


Fig. 6. Mean Rohrer index (W/H^3) for ages 6–17.5 years; also shown, measurements for subjects >1 SD above mean weight for age.

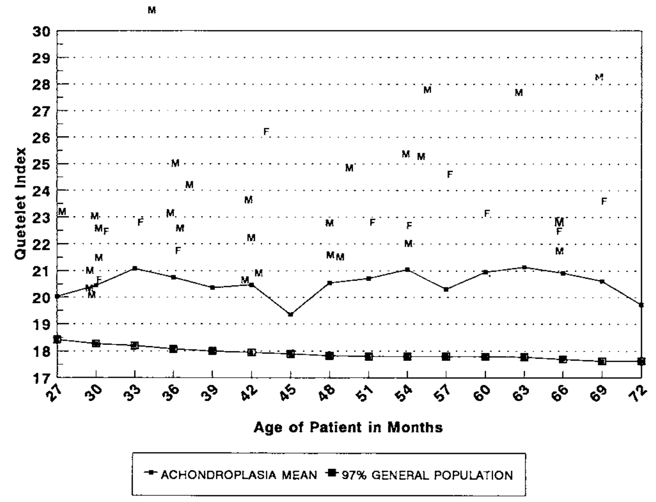


Fig. 7. Mean Quetelet index (W/H^2) for ages 27–72 months; also shown, the general population 97th centile, and individual measurements for those >1 SD above mean weight for age.

as "obese" at the time of personal interview had triceps values above, and often twice that of, the mean (Fig. 5). Between age 3–6 years, the Quetelet index (W/H^2) shows no correlation with height ($r = 0.03$), but a reasonable correlation with weight ($r = 0.59$, $P < 0.001$). As would be expected with rhizomelic short stature, the values run well above those of the general population, but are relatively constant. Thirty-seven of the 40 children whose weights were at least 1 SD above the mean for age had W/H^2 values above the mean (Fig. 7). In fact, the values were often very high. Only 1 of the 3 children with values below the mean was actually over age 3 years. These 3 children, and 3 others whose values were close to the mean, were all found to have heights ≥1 SD (usually >1.5) above the mean for age. Thus, it seems that the taller, and hence less disproportionate children, will have W/H^2 values that tend more towards the average population range. From age 6–18 years the Rohrer index (W/H^3) appears to be the best index but, although it does not correlate with height ($r = -0.03$), it shows a relatively poor correlation with weight ($r = 0.42$, $P < 0.001$). However, 16 of 19 children whose weight was at least 1 SD above the mean for age were well above, and only 1 was actually below, the mean W/H^3 for age (Fig. 6). The 9-year-old and 13-year-old who were just above the mean were relatively tall for their peer group, while the 17.5-year-old was of average height.

An individual W/H measurement is a poor indicator of body fat because it is highly correlated with height. However, comparison of an individual W/H ratio with the mean and SD of the population mean for their height provides a useful indication of whether the person is relatively heavy or light for their height. We have provided standardized W/H curves for use with achondroplasia. One may question whether, if there is truly a problem with obesity in achondroplasia, it is valid to use curves derived from a general population of achondroplastic individuals. Would it not be preferable to use curves based upon those selected to exclude obesity? Indeed, 3 subjects who were considered grossly obese, and whose single W/H value caused an increased SD out of keeping with the trend, were excluded from this analysis. A problem with the selective approach is that it accepts the presumption that obesity is common and will involve a great deal of subjectivity in who is excluded from analysis. It should also be noted that the vast majority of childhood measurements were taken at a single center where children are followed every 6 months to age 10 years, and yearly thereafter, and where there is a strong, and largely successful, emphasis on the avoidance of obesity.

A reasonably conservative approach would be to aim at having children with achondroplasia stay within 1 SD of the mean W/H curve. Other tools, such as skinfold calipers, cautious use of indices, and an experienced clinical eye, can help distinguish the muscular from the obese individual. The observations on teens and adults are less numerous and less controlled, and undoubtedly contain a broader representation of individuals who are overweight. Until more adult data are available, it is probably reasonable to have these individuals aim at keeping their W/H ratio near the population mean.

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